

The development of an Equipment Management System for a parts distribution centre

by

Dakalo Deborah Funyufunyu

25267770

Submitted in partial fulfilment of the requirements for the degree of

BACHELORS OF INDUSTRIAL ENGINEERING

in the

**FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND
INFORMATION TECHNOLOGY**

UNIVERSITY OF PRETORIA

October 2009



**UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA**

Executive Summary

Nissan South Africa (NSA) was established about 40 years ago initially by importing and locally assembling completely knocked down vehicles. This was followed by the establishment of the NSA manufacturing facilities in Rosslyn near Pretoria. The South African plant produces a comprehensive range of passenger cars, light, medium and heavy commercial vehicles and its recreational and other specialized vehicles.

The company's after-sales department has identified an area of improvement at the parts distribution centre. The material handling equipment at the parts distribution centre has been identified as a bottleneck of the customer order fulfilment process. For this reason management requires a material handling equipment study that will focus on optimizing the equipment utilization.

An Equipment Management System that stores and processes valuable equipment information in the warehouse was developed. The logical design model of the EMS was developed to indicate what the system capabilities and limitations are. These capabilities and limitations were modelled into the physical design ensuring that stakeholder requirements were met. The impact of the complete system will be to increase throughput by making the logistics system respond quickly to customer requirements.

It was found that many breakdowns can be associated with forklifts. This is due to the age of the forklifts and the environment in which they are operated. It is recommended that Nissan SA rents their forklifts from an external company in order to reduce their operating costs and recurring breakdowns. If the old equipment that keep breaking down is replaced an estimated R200 000 can be saved annually.

Table of Contents

Chapter 1 : Project plan	6
1.1. Introduction and Background	6
1.2. Problem Statement	7
1.3. Project Aim	7
1.3.1. Objectives.....	7
1.3.2. Constraints	8
1.4. Project Scope	8
1.5. Deliverables	9
Chapter 2 : Literature review	10
2.1. Introduction	10
2.2. Environment analysis: parts distribution centre	10
2.2.1. Characteristics of the Material handling Equipment.....	11
2.2.2. Material handling principles.....	12
2.2.3. Warehouse design factors	14
2.3. Industrial Engineering Methods, Tools and Techniques	14
2.3.1. Simulation	14
2.3.2. Asset performance management model	16
2.3.3. Resource utilization	18
2.3.4. Maintenance.....	18
2.3.5. Life cycle cost (LCC)	19
2.3.6. Economical life of equipment.....	20
2.3.7. Information System design	22
2.4. Selection of IE Methods, Tools and Techniques	25
2.4.1. Equipment Management System.....	25
2.4.2. Equipment identification and classification.....	25
2.4.3. Information system design.....	26
2.5. Conclusion	28

Chapter 3 Development of System design	29
3.1. User requirements	29
3.1.1. Functional decomposition diagram	30
3.1.2. Non-functional requirements.....	30
3.2. Logical design.....	31
3.2.1 Entity relationship diagram	33
3.2.2. System triggers	33
3.3. Evaluation and conclusion	35
3.2.1 Critical findings and recommendations	35
3.2.2. Conclusion.....	37
3.4. References	38
3.5. Appendix.....	40

Table of Figures

Figure 1 Warehouse operations indicating the use of MHE. (Coyle et al, 2003)	13
Figure 2 The steps of developing a simulation model.....	15
Figure 3 Equipment life cycle	17
Figure 4 Economical life.....	21
Figure 5 Economical life calculations	21
Figure 6 Functions of an Equipment management system.....	27
Figure 7 System Context Diagram	29
Figure 9 Entity Relationship Diagram (ERD)	32
Figure 10 Equipment information flow	34

List of tables

Table 1 Equipment Classification System	26
Table 2 Cardinality notations (Whitten et al. 2007)	31

Chapter 1 : Project plan

1.1. Introduction and Background

Nissan South Africa is part of a global company that was started in 1911 when the Kwaishinsha Automotive Company was formed to produce the first Datsun cars in Japan. According to their website the company was registered in the early 30s as the Nissan Motor Company and became a global manufacturer when it started extending its production facilities to the United States and United Kingdom.

Nissan South Africa (NSA) was established about 40 years ago initially by importing and locally assembling completely knocked down vehicles. This was followed by the establishment of the NSA manufacturing facilities in Rosslyn near Pretoria. The South African plant produces a comprehensive range of passenger cars, light, medium and heavy commercial vehicles and its recreational and other specialized vehicles.

The focus of the project will be on the NSA after-sales parts distribution centre. This warehouse is used to store all after-sales vehicle parts that are distributed to Nissan car dealers across South Africa. Warehouse management has identified the utilization of material handling equipment as a bottleneck in the warehouse. Addressing this problem is important to Nissan because better utilization of these equipments will lead to increased throughput and better productivity. This report will outline the approach that will be taken to address the problem.

1.2. Problem Statement

Nissan SA after-sales distribution centre has an inadequate reporting system of Material Handling Equipment (MHE) utilization and management. The lack of data on the performance of MHE may lead to uninformed decisions about maintenance management, economic life and replacement decisions as well as equipment and equipment supplier selection.

1.3. Project Aim

The aim of the project is to develop a reliable Equipment Management System (EMS) that will be used to facilitate an increase in effective equipment utilization by capturing valuable MHE data. The information system will be used to track and monitor equipment states, maintenance task schedules and the calculation of equipment life cycle costs. The maintenance management subsystem will be able to track the costs of maintaining each piece of equipment, including the costs of parts replaced or repaired. Reports generated by the EMS will help management set policies for better equipment management in the future.

1.3.1. Objectives

- Develop an Equipment Management System for the collection and storage of equipment performance and management data; this includes availability, utilization, life cycle costs and equipment value.
- From the information system, analyse and evaluate different MHE for various operations to determine their effectiveness and whether they should be rented or purchased.
- Develop a maintenance management subsystem that will be used to plan for preventative maintenance and to capture information about maintenance tasks and costs.

- Develop a standardised MHE identification and classification system.

1.3.2. Constraints

The objectives are subject to the following constraints:

- The University of Pretoria time lines.
- Nissan policies and management issues.
- Availability and attainability of the necessary data.

1.4. Project Scope

The project scope covers the MHE used at the Nissan SA after-sales parts warehouse. It will focus on the utilization of the following types of MHE used in the warehouse:

- Counterbalance lift trucks (forklifts)
- Side stacker machines (Reach trucks)
- Order picking machines
- Pallet trucks

The Equipment Management System will cover the use of the MHE within the warehouse and at the receiving and shipping docks. The system user responsible for the input of data will be triggered by any material flow that is required either at the docking areas, staging or storage areas. The aim of the maintenance subsystem will be to make the maintenance data gathering much easier and to ensure availability of equipment history for better planning.

1.5. Deliverables

- Equipment utilization information for each class of MHE.
- Standardised material handling equipment identification system.
- An equipment management system that can be used to make decisions about the MHE through a daily reporting system.
- Maintenance schedules that will increase equipment availability reduce breakdowns and maximize equipment life.
- Improvement of equipment utilization and comparison of rent versus buy decisions.

Chapter 2 : Literature review

2.1. Introduction

At the outset, an engineer must be up to date with the most recent knowledge and ideas that have been established in their area of research. It is professional to consider what others know about the subject, to identify knowledge gaps and determine consensus about the topic of research. The purpose of this literature review was to identify current methods, tools and techniques used in the study of equipment utilization and management. The selected combination of which will be used to formulate a solution for Nissan SA. The review of literature was conducted by means of library searches, internet searches, informal interviews and observations at the Nissan SA and Renault parts distribution centres.

Warehouses are often termed distribution centres for the simple reason that they are a means of distributing semi-finished or finished goods to the end-user. Of course we may not neglect the storage function of the warehouse, but every product in the warehouse is stored with the intention of retrieving it sometime in the near future. In order to fulfil the distribution function within and around the warehouse more often than once, the need for material handling equipment (MHE) arises. As a distribution centre expands and starts to accommodate over 100 000 product lines, it is obvious that the need for effective MHE management arises.

2.2. Environment analysis: parts distribution centre

After observing the use of MHE in and around the warehouses, it has become apparent why management has the need to know about the utilization of such equipment. After investing millions of rand in equipment, the ideological situation is to want to see it utilized 100% of its available time. Unfortunately in reality machines breakdown due to failure in their systems, and sometimes due to negligence and ultimately they become obsolete and need to be disposed off.

Figure 1 depicts the use of material handling equipment to carryout warehouse operations. MHE are triggered by such operations as the arrival of merchandise from suppliers, the fulfilment of customer orders and bin maintenance. Bin maintenance in this case will only refer to the removing of stock from an area that is difficult for pickers to reach to a bin within reach. It can also be the removal of parts from the wrong bin according to records, to the correct bin.

It was found that the utilization of material handling equipment is affected mostly by maintenance and other material handling system variables. Factors like floor layouts determine the distances travelled by MHE. Certain techniques and tools can be employed to optimize such factors, thus improving the utilization of equipment and maximizing equipment life. These techniques will be discussed briefly later in the document. Before ways of improving MHE utilization are discussed, the type of equipment used will be described.

2.2.1. Characteristics of the Material handling Equipment

The following MHE form part of the scope of the study at NSA:

1. Pallet trucks

A pallet truck is designed to handle pallets or similar type loads. The truck is automatic and consists of two forks that when lowered will fit into the fork pockets of pallets or under other skid-type loads. (Lane: 2004). In the Nissan warehouse the pallet truck is mostly used with a collapsible pallet to pick orders of small boxes in the fast moving stock area. These trucks are restricted to shorter distances and can only reach lower heights.

2. Forklifts

There are two classes of lift trucks: electric/battery and internal combustion (petrol or diesel). In the Renault warehouse where lift trucks are used in the warehouse, only battery powered ones are allowed inside because diesel trucks emit fumes that may be harmful. Lift trucks are not used for the storage and retrieval of items in the Nissan warehouse due to space constraints; they are only used at the docking and external storage areas. These trucks have a relatively low cost and they are flexible in most cases.

3. Picker machines

This machine is designed only to move up and down the aisle with the operator picking orders or replenishing locations. The operator controls the truck from the platform and by placing a pallet or another container on the forks the operator can then move down an aisle and rise up to a location to replenish or pick. (Lane: 2004)

4. *Side stackers*

These trucks load and unload from one side and therefore do not need to turn in the aisle in order to access storage positions. They can reach the highest storage areas in the warehouse.

2.2.2. Material handling principles

The following material handling principles will be applied in the development and design of this project:

- *Life cycle cost principle*: this includes all cash flows that will occur from the moment a rand is spent to procure a piece of equipment until the equipment is obsolete.
- *Standardization principle*: this means less variety and customization in the methods and equipment employed in material handling.
- *Utilization principle*: plan for optimum utilization of handling equipment and labour.
- *Maintenance principle*: plan for preventative maintenance and scheduled repairs of all handling equipment.
- *Safety principle*: provide suitable methods and equipment for safe handling.

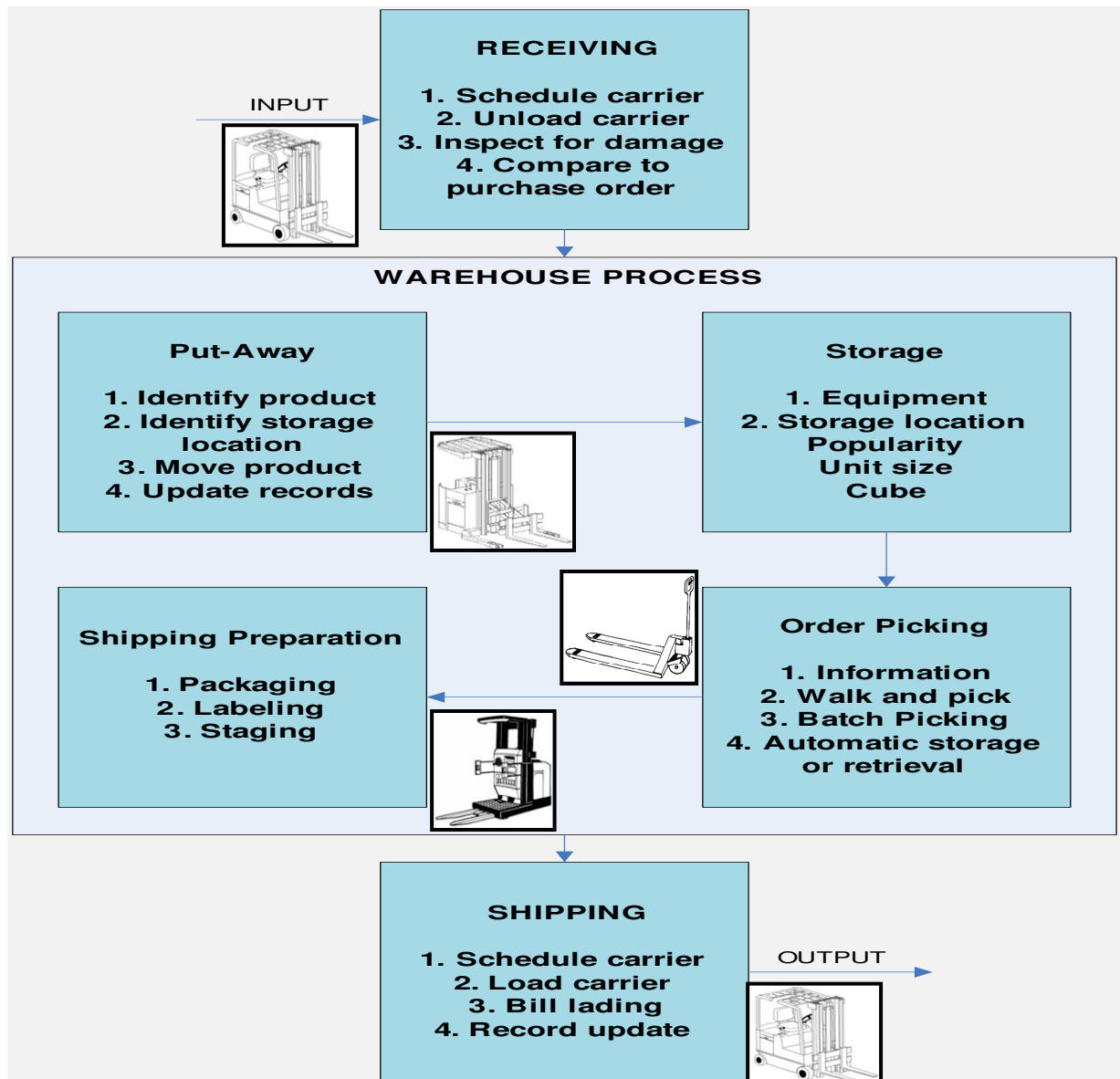


Figure 1 Warehouse operations indicating the use of MHE. (Coyle et al, 2003)

2.2.3. Warehouse design factors

The design of a warehouse floor layout is chosen from numerous generated alternatives. One of these alternatives is ultimately chosen because it minimizes the distance travelled by both MHE and the workers, minimizes processing time and maximizes warehouse throughput. Floor layout designs consider such things as the design of aisles, bin location and equipment zoning areas. According to Hassan (2002) determining the number of aisles, their location, orientation, length and width is an important step in designing the warehouse due to its impact on space needs, operations, material handling and storage assignment.

The Nissan SA warehouse was designed with the same layout considerations in mind. Receiving operations used to take place in front of the warehouse and shipping operations were at the back of the warehouse. MHE was aligned to such a layout. Currently the warehouse has receiving and shipping operations taking place on the same side of the warehouse. This leaves long travelling distances for the picking of products at the back of the warehouse. Long aisles are mainly meant for automatic material handling systems, because they wear out equipment especially when non-value added travels occur frequently.

The floor layout can be optimally designed in order to increase equipment utilization and efficiency, but the optimal design is better implemented during the initial design of the warehouse. When floor layouts are complete, the zoning areas of the MHE can be determined according to the frequency of picking of a particular product and its location. Zoning areas are chosen in such a way that minimizes unnecessary travel of MHE.

2.3. Industrial Engineering Methods, Tools and Techniques

2.3.1. Simulation

Simulation modelling is the development of a computer model that represents reality. It is a suitable tool for capturing the dynamic nature of operations in an environment such as a warehouse. The following are an example of dynamic factors that influence the movement of material within a facility (Celik and Gunal: 2006).

- Delivery schedules

- Availability of material handling equipment
- Routes of movement
- Aisle width

Simulation could be used to capture the utilization of a particular piece of equipment and the amount of time the equipment is idle or to study the effectiveness of different forms of MHE by considering their detailed parameters such as speed, movement paths and traffic and control logic. For example the generic simulation model that was developed by Celik and Gunal (2006) provides the following outputs automatically; (i) throughput of the assembly plant, (ii) traffic congestion based on trips per hour on aisles based on a fixed production schedule, and (iii) material handling equipment requirements, utilization, and capacity.

The applications of simulation are broad but they require careful selection of data that best represents the actual system and even then, the best simulation model never truly represents the system 100% correctly. The best thing about simulation models is that changes can be tested on the model without affecting the real system. For example, the impact that purchasing four more forklifts will have on the level of throughput can be tested on the model. Figure 2 (Kelton et al: 2007) indicates the basic steps followed in the development of a simulation model.

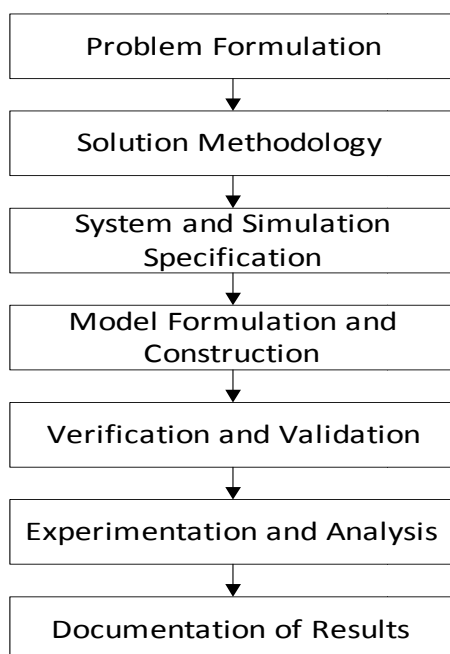


Figure 2 The steps of developing a simulation model

2.3.2. Asset performance management model

There has been a shift in industry from maintenance management towards asset management. This is because of the increasing need for reliable and operational equipment and effective assets at optimum life cycle costs. Jooste and Page (2004) developed an Asset Performance Management Model (APM²) that is fully integrated with business processes and strategies.

The APM² is characterized by the following four features:

- It gives both a financial and non-financial view of asset performance
- Asset performance is directly linked to strategic business objectives
- It facilitates decision making and problem solving at different managerial levels
- It improves asset control and encourages continuous improvement

Principles of performance and asset management

Performance can be seen as a collection of processes that will assist stakeholders in taking appropriate actions to create a performing organisation in the future (i.e. more efficient and effective). When stakeholders take such actions they must base their decisions on quantitative information; collected asset data (Jooste and Page: 2004). They go on to describe performance management as the process of collecting and measuring performance data, interpreting the data and identifying any problems and making decisions to improve performance, within the scope of the scope of the business goals.

“There is currently a great need to manage assets effectively and efficiently in order to attain maximum return on investment.” Jooste and Page (2004) affirms that this can only be achieved by considering the entire life cycle of the asset.

Piperakis and Pouris (2006) agree with the management of equipment by taking the whole life cycle into account. The figure below illustrates how they take equipment life cycle into account for the management of different research equipment. Life cycle costs are discussed in more detail in section 3.5.

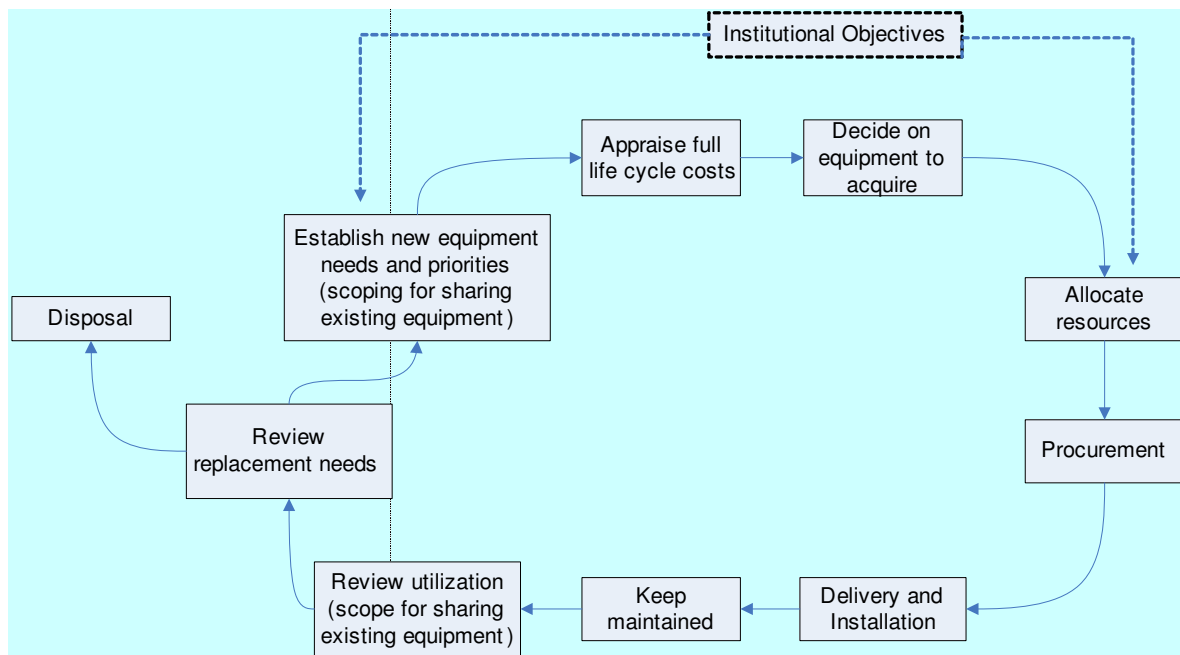


Figure 3 Equipment life cycle

Performance Measures

The two main measures selected for the APM2 are the Overall Equipment Effectiveness (OEE) and Overall Plant Performance (OPP). OPP is a measure that gives an indication of asset performance relative to each minute of the clock (operation time and authorized downtime). (Jooste and Page: 2004)

$$OEE = Availability \times Performance \times Quality$$

$$OPP = Utilization \times OEE$$

$$Quality = \frac{Good\ production}{Total\ production}$$

$$Performance = \frac{Actual\ production \times Theoretical\ production}{Operation\ time}$$

Where good production = Gross production – start up defects – quality defects

This model can be adapted for the material handling equipment purposes.

2.3.3. Resource utilization

According to Chase, Jacobs and Aquilano (2007) utilization is the ratio of the time that a resource is actually activated relative to the time that it is available for use. Utilization is calculated according to the following formulae:

$$\frac{\text{Loading time}}{\text{Total time}} = \frac{\text{Total time} - \text{Authorized downtime}}{\text{Total time}}$$

Where Loading time = Total time- Authorized downtime

Authorized time is a result of decisions and policies set by management, for example time scheduled for preventative maintenance is authorized downtime. (Jooste and Page, 2004)

2.3.4. Maintenance

An effective material handling system must have a good maintenance system for the material handling equipment. Maintenance is defined as “to keep in an existing state (as of efficiency, repair and validity): to preserve from failure or decline (Eastman 1987). Maintenance activities may include the following:

- Repairing components and assemblies
- Replacing defective parts
- Adjusting the system for maximum operating efficiency
- Routine preventative actions such as lubrication, inspecting MHE and keeping maintenance records necessary for effective work.

All these actions will increase equipment availability and improve utilization. Maintenance ensures that equipment is kept in a state of operation or restored to such a state when it breaks down. Breakdown can contribute to production losses due to product losses. A good

maintenance system is also an equipment management system ensuring that equipment is kept functioning at maximum efficiency. Eastman (1987) identified these as the objectives of a good maintenance system:

- To keep the system operating at highest possible efficiency.
- To minimize lost production and downtime from system failures and breakdowns.
- To perform the maintenance function as efficiently and economically as possible.

2.3.5. Life cycle cost (LCC)

Life cycle cost is commonly accepted as the customer's (buyer's or end user's) total cost plus other expenses that are incurred during the lifetime of the product (Borghagen:2004). LCC include the purchasing cost as well as all future costs for the operation and maintenance of the product until it becomes obsolete.

Why calculate LCC?

LCC is helpful in the comparison of different manufacturers of equipment and in decisions of whether to buy or rent equipment. LCC should become a tool for product selection as well as for guidance of the product design to accomplish the desired operational performance at the lowest total cost. LCC gives the company an overview of the amount of money spent on a piece of equipment over its lifetime. This is important because companies want to choose the equipment that costs the lowest to support throughout its lifetime.

LCC calculation model

The primary cost elements in the LCC calculation model are the following according to Borghagen (2004):

$$\mathbf{LCC = LCA + LSC}$$

Where LCC = life cycle cost

LCA = acquisition cost (product price)

LSC = life support cost (user cost)

In a normal case the following cost elements will be included in LSC:

- Cost for corrective maintenance, on-site as well as workshop maintenance
- Cost for preventive maintenance
- Cost for spares, initial investment, and substitutes for future consumption
- Cost for maintenance tools and equipment
- Cost for documentation
- Cost for training
- Cost for operation
- Cost for lost production due to product downtime (unavailability time)
- Cost for those remaining items that are deemed significant

2.3.6. Economical life of equipment

The economical life of a piece of equipment is the period over which it provides the best method for performing its intended task. When a superior method of performing the task is developed, then the machine has become obsolete and must be replaced (Chase et al: 2007). This measure together with the depreciation of equipment is used by organizations to make decisions about equipment replacement. Depreciation is the decline in the value of equipment due to wear and tear. If replacement decisions are not made a company could continue to spend money on equipment that spends most of the production time broken down from failure, resulting in a waste of money. The figure below indicates the economical point for the replacement of equipment.

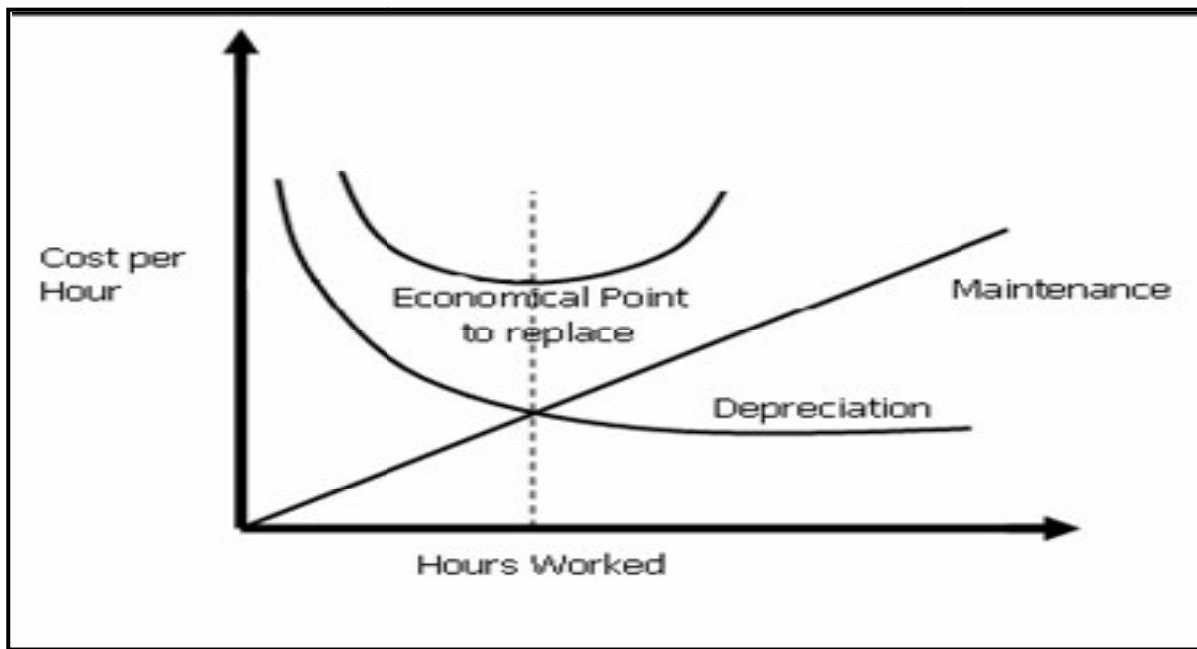


Figure 4 Economical life

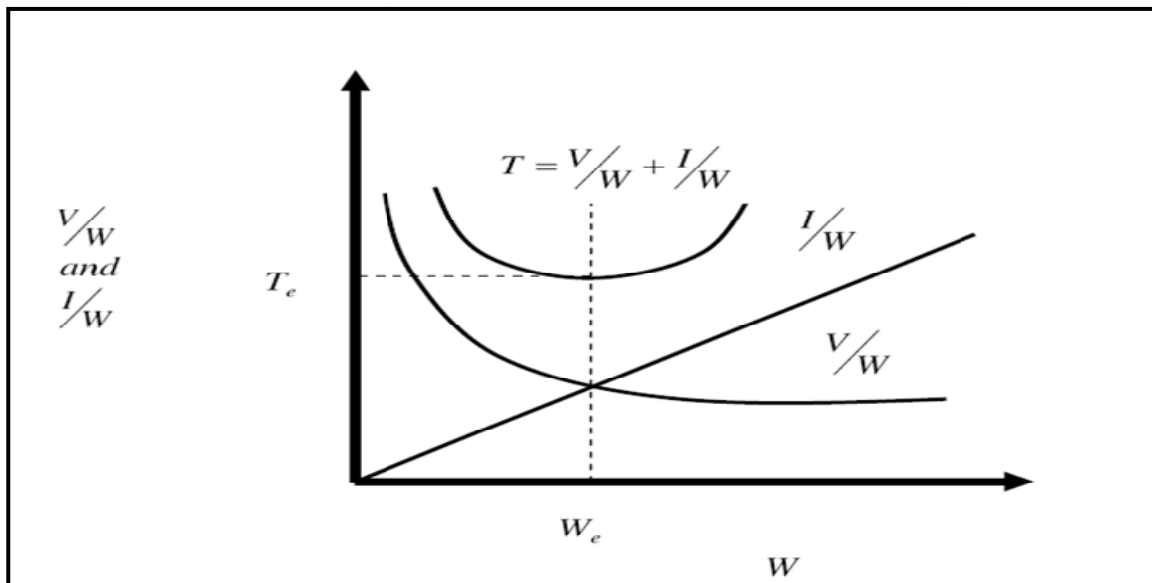


Figure 5 Economical life calculations

Where W = cumulative hours worked per period

V = Salvage value or book value

I = Maintenance costs

The economic life curve **T** is given by the sum of the salvage value over the cumulative hours worked and the maintenance cost over the cumulative hours worked. The minimum total cost is derived as follows:

—
—

Where — is the maintenance index

The cumulative hours worked can be collected from the pallet truck daily checklist that the operators use to record information about equipment.

2.3.7. Information System design

A system is a set of interrelated components that work together to achieve a common objective; this can be a non-computerised system. Bentley and Whitten (2007:6) define an information system as an arrangement of people, data, processes, and information technology that will interact to collect, process, store and provide as a result the information needed to support an organization's functions. Therefore an information system (IS) can be any system in an organization that is computerized to make the collection, storage, analysis and retrieval of data more efficient.

System stakeholders

A system stakeholder is anyone who may have an interest in the proposed information system; this includes for example people who will directly use it or those who will receive reports from the IS. The system owners are management; in this case industrial engineers. The system users will be the maintenance staff, equipment operators and data-capturer.

IS development methodology

The FAST methodology will be used to develop the equipment management system for Nissan SA. This method consists of eight development phases namely (Bentley and Whitten: 2007):

- Scope definition
- Problem analysis
- Requirements analysis
- Logical design
- Decision analysis
- Physical design and integration
- Construction and testing
- Installation and delivery

Phase 1: Scope definition

The scope phase will determine whether the problem is worth solving and if it is, this phase then sets the boundaries for such a project. The scope definition is triggered by some combination of problems, opportunities and directives. For the Nissan warehouse the opportunity was identified to start gathering information about the utilization of material handling equipment. This information will aid in the effective management of equipment. Management will be able determine the required number of MHE, to make decisions on whether to continue buying equipment or to rent it and equipment performance information will aid in the selection of MHE suppliers in the future. The information system will focus on the MHE that is used in the shelving area where larger parts are stored. This equipment include: forklifts, picking machines, side stackers and hand pallet jacks.

Phase 2: Problem analysis

The Nissan warehouse has an inadequate reporting system of Material Handling Equipment (MHE) utilization and thus they cannot plan for optimum utilization of equipment. This lack of information on MHE leads to preventative maintenance that is not well planned. In this phase system improvement objectives were determined. The current system has limited the utilization of MHE due to the equipment being idle from breakdowns. The information system will be developed so as to aid management in making informed decisions about the utilization of equipment, the replacement of equipment and the effectiveness of preventative maintenance in maximizing uptime.

Phase 3: Requirements analysis

This phase determines the business requirements for the system. In other words what management expects from the end product. The main requirement of the information system in this case will be to report on the utilization of material handling equipment and the effects thereof (i.e. maintenance, economic life and costs). The non-functional requirements of the system are those that do not affect how it functions technically. This includes the system being user friendly, secure, improving the method of data capturing and making use of easy and recognisable terminology.

Phase 4: Logical design

During this phase business user requirements are translated into a system model that depicts only the business requirements. This does not include any technical design or implementation of the requirements.

Phase 5: Decision analysis

Different alternatives on constructing an information system are considered in relation to the business requirements identified and the logical design models. In this phase the requirements together with other questions that must be answered will be the base for determining what the system must achieve.

Phase 6: Physical design and integration

In this phase the requirements defined by the end user are translated into a system model. The flow of information into the system and out of the system will be clearly indicated. Considerations will be made of how the system being designed will be integrated with other systems in the business.

Phase 7: Construction and testing

This is the physical building of the access database. The necessary data will then be captured into the system to test and verify that it is fulfilling the business requirements and designed specifications.

Phase 8: installation and delivery

The implementation of the information system does not form part of the project. The construction and testing phase will allow management to test the benefits of the system and at a later stage this system may be implemented. An operating and training manual will be developed, that can be used when the system is implemented.

2.4. Selection of IE Methods, Tools and Techniques

2.4.1. Equipment Management System

The development of an equipment management system will require the combination of various IE methods and tools. It is the current chosen methodology for solving the problem. The management system cannot automatically manage equipment, but it will aid in the effective management thereof. Its success will be highly dependent on the dedication of the workers to use it correctly and this depends on the effectiveness of training provided.

2.4.2. Equipment identification and classification

An equipment management system will require that equipment be numbered with a unique identifier in order to be maintained on the database. Equipment is currently identified by just giving it a sequential number. Although this is relatively easy to implement, it gives the users no information about what type of equipment a particular number refers to.

Cato and Mobley (2002) suggest that the equipment identifier must have meaning so that the type of equipment it represents can easily be determined. The following method of equipment identification will be used:

TT-C-NN

Where TT = Type C = Class NN= Manufacturer

The class is represented by one digit because the class of equipment will not go beyond nine even in the future. MHE can either use electricity/battery, diesel or hydrogen cells. The class will have 9 digits, running from 1 to 9. The code to identify the name of the manufacturer uses two digits that run from 01 to 99. The table below indicates the proposed classification system.

Type	Type Description	Class	Class description	Manufac. code	Code description
FL	Forklift	1	Electric	01	Nissan
				02	Crown
		2	Diesel	03	Prime mover
				04	Nichiyu
OP	Order Picker	1	Electric	01	Nissan
				02	Crown
		2	Other	03	Prime mover
				04	Nichiyu
RT	Reach Truck	1	Electric	01	Nissan
				02	Crown
		2	Other	03	Prime mover
				04	Nichiyu
PT	Pallet Truck	1	Electric	01	Nissan
				02	Crown
		2	Other	03	Prime mover
				04	Nichiyu

Table 1 Equipment Classification System

For example, FL-1-01 is the class of electric forklifts manufactured by Nissan. This items could be selected to view their breakdown history, utilisation or cost of maintenance in order to see if Nissan is the best brand for the particular equipment.

2.4.3. Information system design

The FAST methodology will be used to develop the equipment management system for Nissan SA. This method consists of eight development phases as described in the literature review: (Bentley and Whitten: 2007):

- Scope definition
- Problem analysis
- Requirements analysis

- Logical design
- Decision analysis
- Physical design and integration
- Construction and testing
- Installation and delivery

The physical database will be constructed using Microsoft Access. This is because it is a familiar product, it is easy to use, it is not too costly and the programmer is knowledgeable with regard to its functions.

Equipment management System functions

The information system is expected to perform the functions as depicted by the diagram below. The EMS processes specific data about the MHE and in order for such functions to be performed the following techniques and methods of calculation will be incorporated into the system:

- Life cycle costing
- Equipment utilization calculations
- Economical life and depreciation
- Preventative maintenance planning



Figure 6 Functions of an Equipment management system

2.5. Conclusion

The improvement of equipment utilization within the warehouse is a data intensive process. It requires a system that can capture store and process data about equipment effectively and efficiently and keep historical data on equipment. Observations made point towards equipment breakdowns as the main source of low equipment availability, but the information system being developed will indicate the utilization of equipment and other aspects of MHE. These aspects should help in the identification of problems and the setting of management of equipment policies. From the research conducted an EMS is expected to increase equipment utilization by over 30%. It is also anticipated that the renting of equipment may be cheaper in the long run and will take the burden of maintenance costs off the company.

Chapter 3 Development of System design

3.1. User requirements

User requirements define what the system is expected to do by the end-user. These requirements say nothing about how the system should technically achieve what is required. The purpose of defining these requirements is to ensure that business requirements are fulfilled when the system is eventually constructed. The project objectives have already been defined and they must now be translated into both functional and non-functional requirements that will be needed to meet those objectives. Functional requirements will be defined in terms of system inputs, processes, outputs and stored data. Non-functional requirements will include performance, ease of learning and use, security and training needs.

The following System context diagram depicts how the system interacts with the world around it and indicates the typical inputs and outputs.

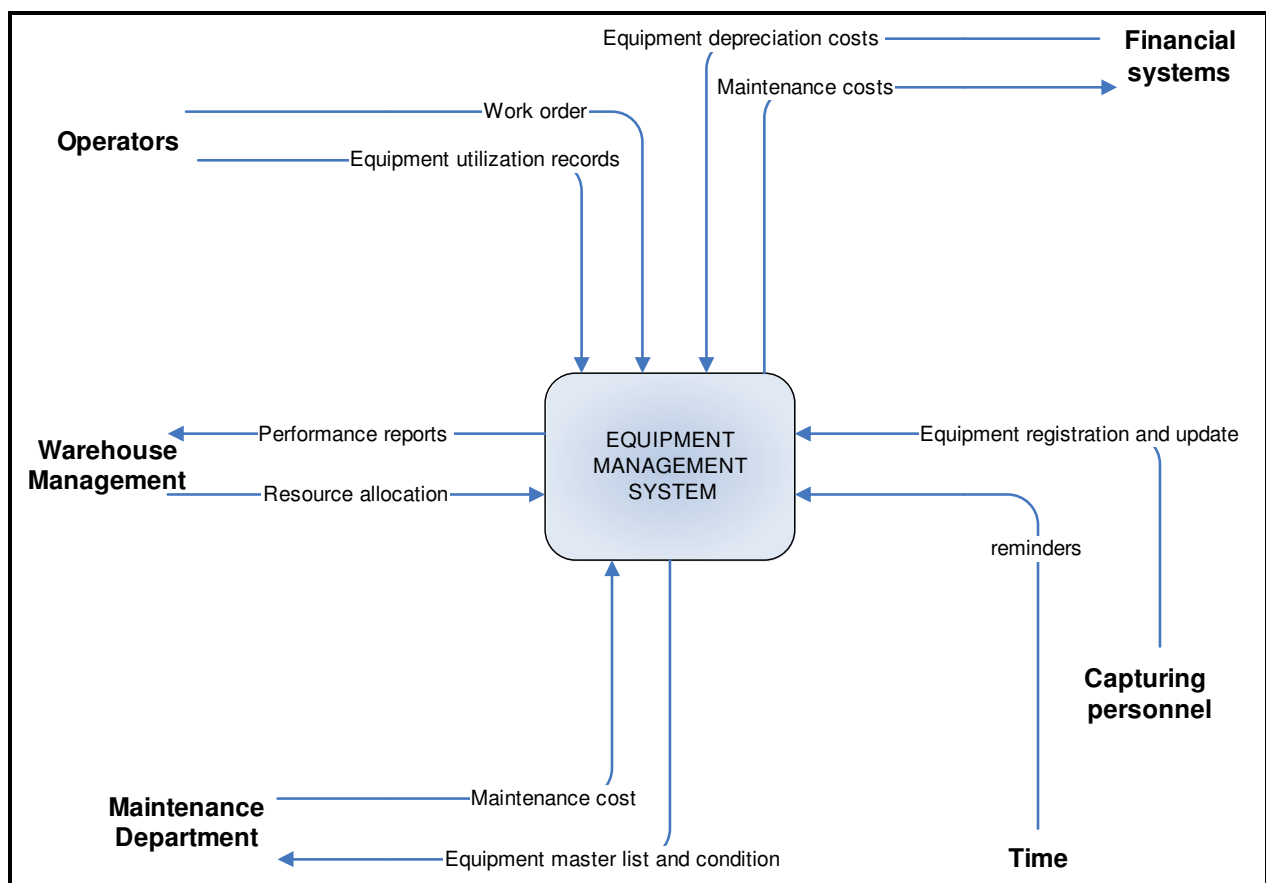


Figure 7 System Context Diagram

3.1.1. Functional decomposition diagram

The functional decomposition diagram shows the top-down structure of the equipment management system. It divides the system into its subsequent subsystems and illustrates the functions performed by these subsystems.

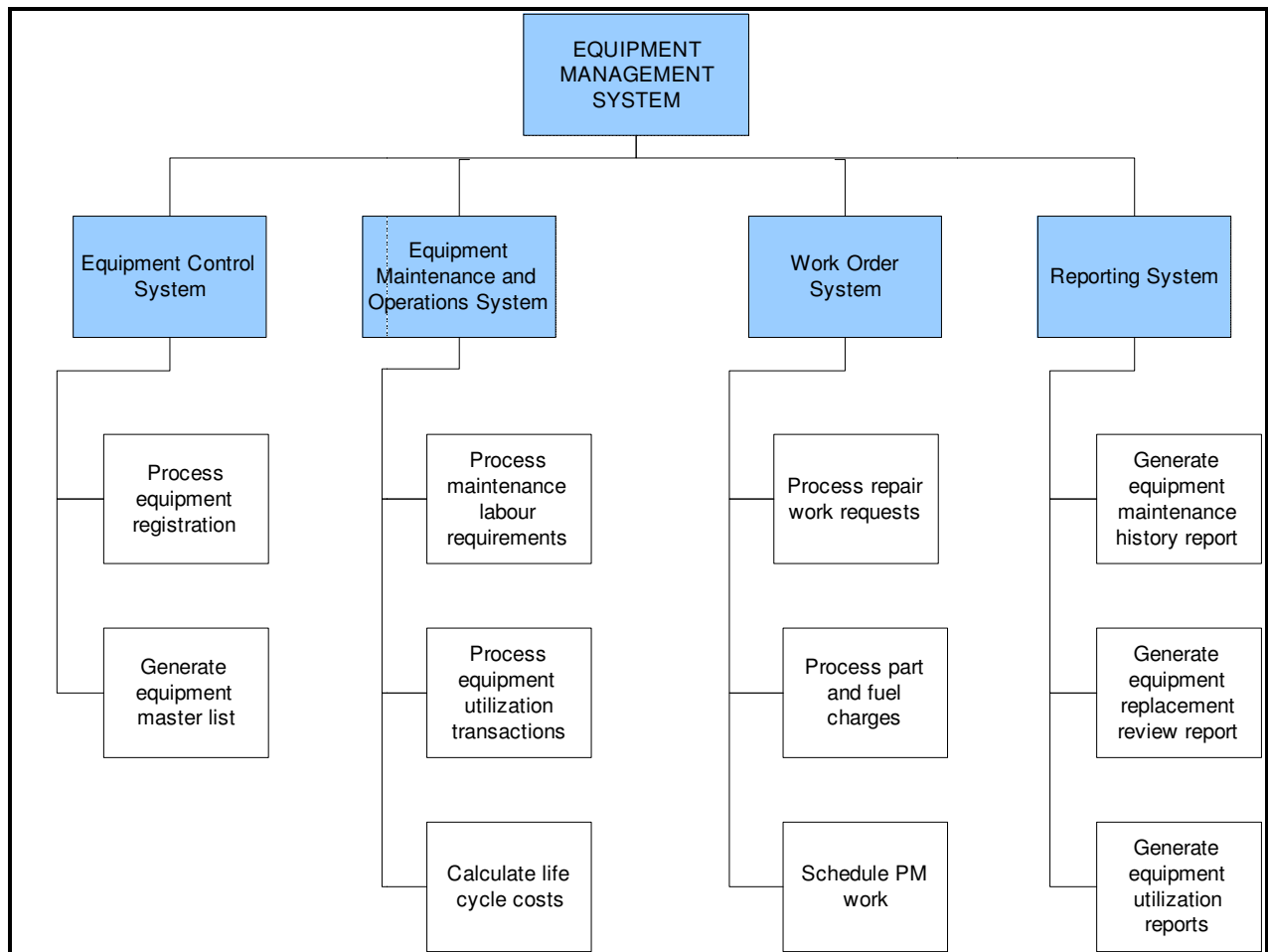


Figure 8 Functional Decomposition Diagram

3.1.2. Non-functional requirements

The system must perform at a relatively good speed, allowing quick access to both management and maintenance reports when required. Only the maintenance department, warehouse management and equipment operators will be able to access and modify records in the system. The EMS must be user friendly easily and easily accessible to the users.

3.2. Logical design

Data modelling is a technique used to define business requirements for a database. It depicts data in terms of entities and relationships described by the data. The entities are objects or things about which an organisation needs to store data. Every entity is described by its attributes or properties and it must also have a key that identifies it uniquely. In the Entity Relationship Diagram (ERD) that was drawn as a preliminary design of the system, the cardinality notations used are explained in table 2.



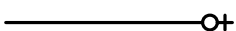



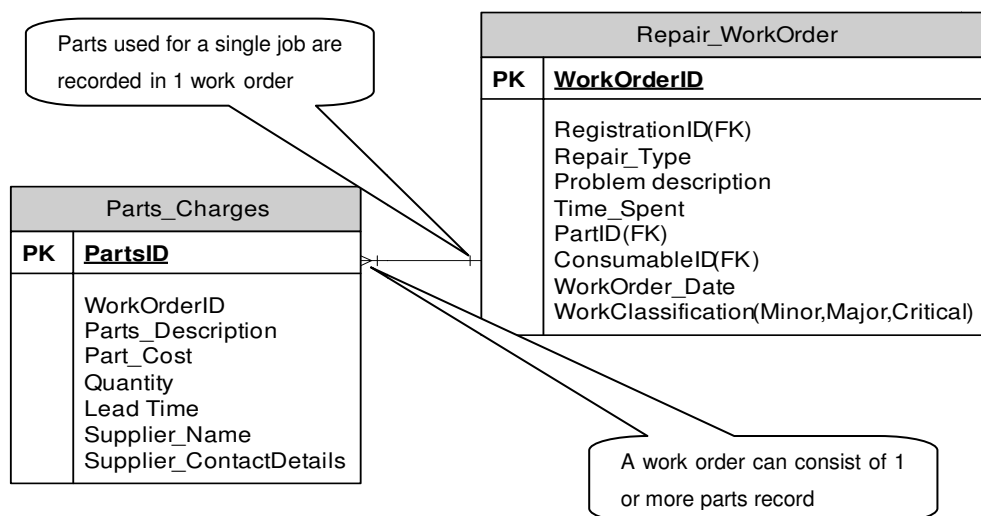
Cardinality Interpretations	Minimum Instances	Maximum Instances	Graphic Notation
Exactly one (one and only one)	1	1	 
Zero or one	0	1	
One or more	1	many(>1)	
Zero, one or more	0	many(>1)	
More than 1	>1	>1	

Table 2 Cardinality notations (Whitten et al. 2007)

Cardinalities can be explained by the following illustration:



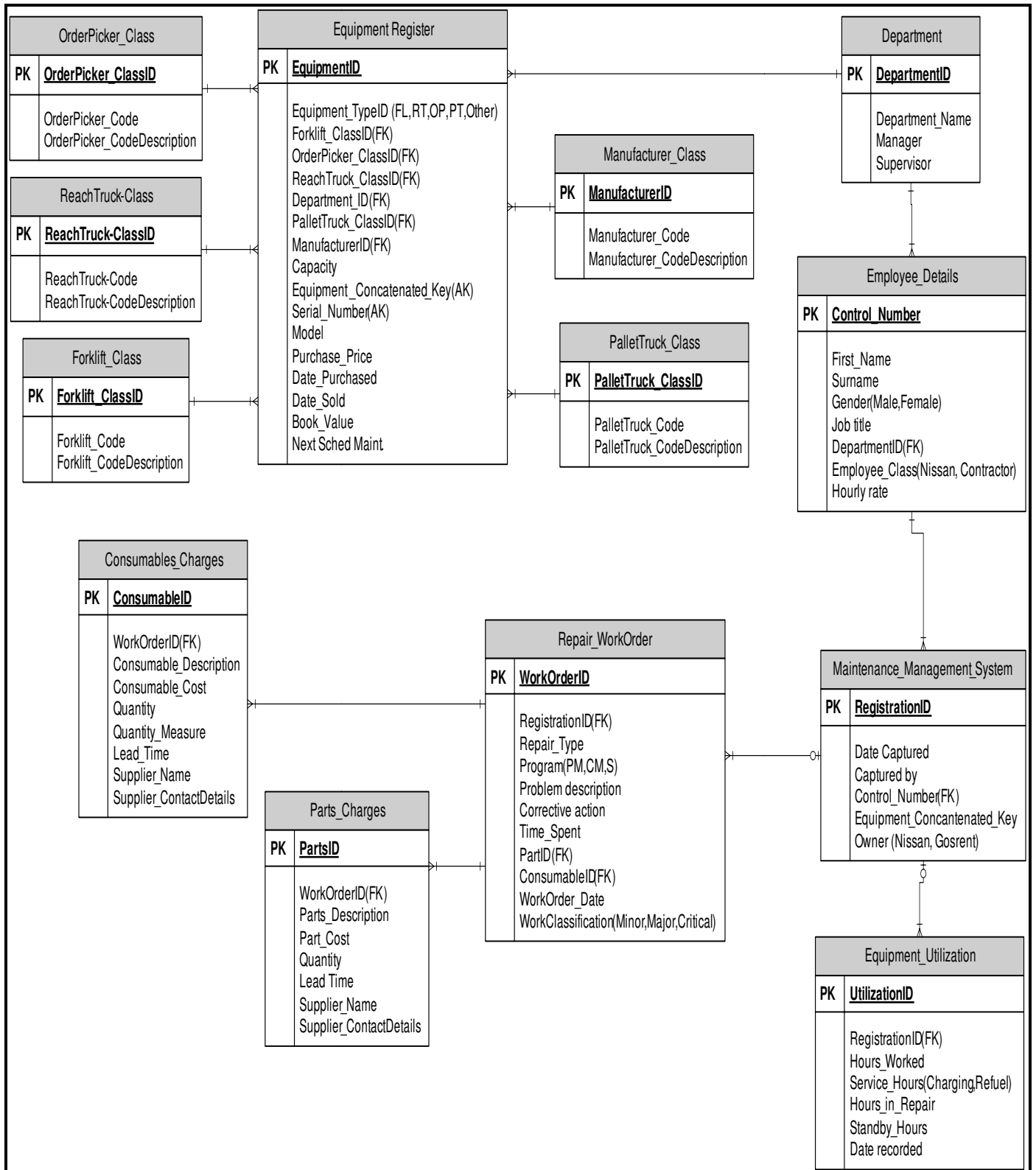


Figure 9 Entity Relationship Diagram (ERD)

3.2.1 Entity relationship diagram

Every piece of equipment that is registered on the database is also classified according to a unique identifier. This identifier as discussed already will give an indication of the type of equipment being dealt with as well as the class and manufacturer of such equipment. This ERD will be transformed into the database during the construction and development phase.

The following important relationships are depicted by the ERD above:

- Any one class of equipment will consist of one or more equipment registrations. For example there are 4 Nichiyu reach trucks in the warehouse and therefore there will be four such registrations under the reach truck class in the system.
- One or many repair shop work orders will be logged for zero or one piece of equipment that has been registered in the maintenance management subsystem. A work order can exist for a piece of equipment that has not yet been registered on the maintenance subsystem.
- Equipment utilization hours are also logged for zero or one piece of equipment that has been registered in the maintenance management subsystem.
- A work order will have a record of one or many parts and/or consumables that were used during a single job.

3.2.2. System triggers

Operators must fill in a checklist before performing any operation with any equipment. The *pallet truck daily checklist* is appended to this document. The operator must perform the first level of preventive maintenance before commencing with their duties. These include checking the condition of the following items on a daily basis and marking the areas needing attention:

- Gauges
- Hooter
- Foot brake
- External leaks
- Wheels
- Steering control
- Park brake
- Battery water and terminals

- Forks
- Pipes and hoses
- Hydraulic oil
- Steering control
- Hydraulic controls

This checklist is not really design to collect any equipment utilisation data. A modified checklist is proposed to ensure that operators are also able to record the times worked by the equipment as well as time of breakdowns. Using the new checklist and proposed work order the following process will be used to save data into the system.

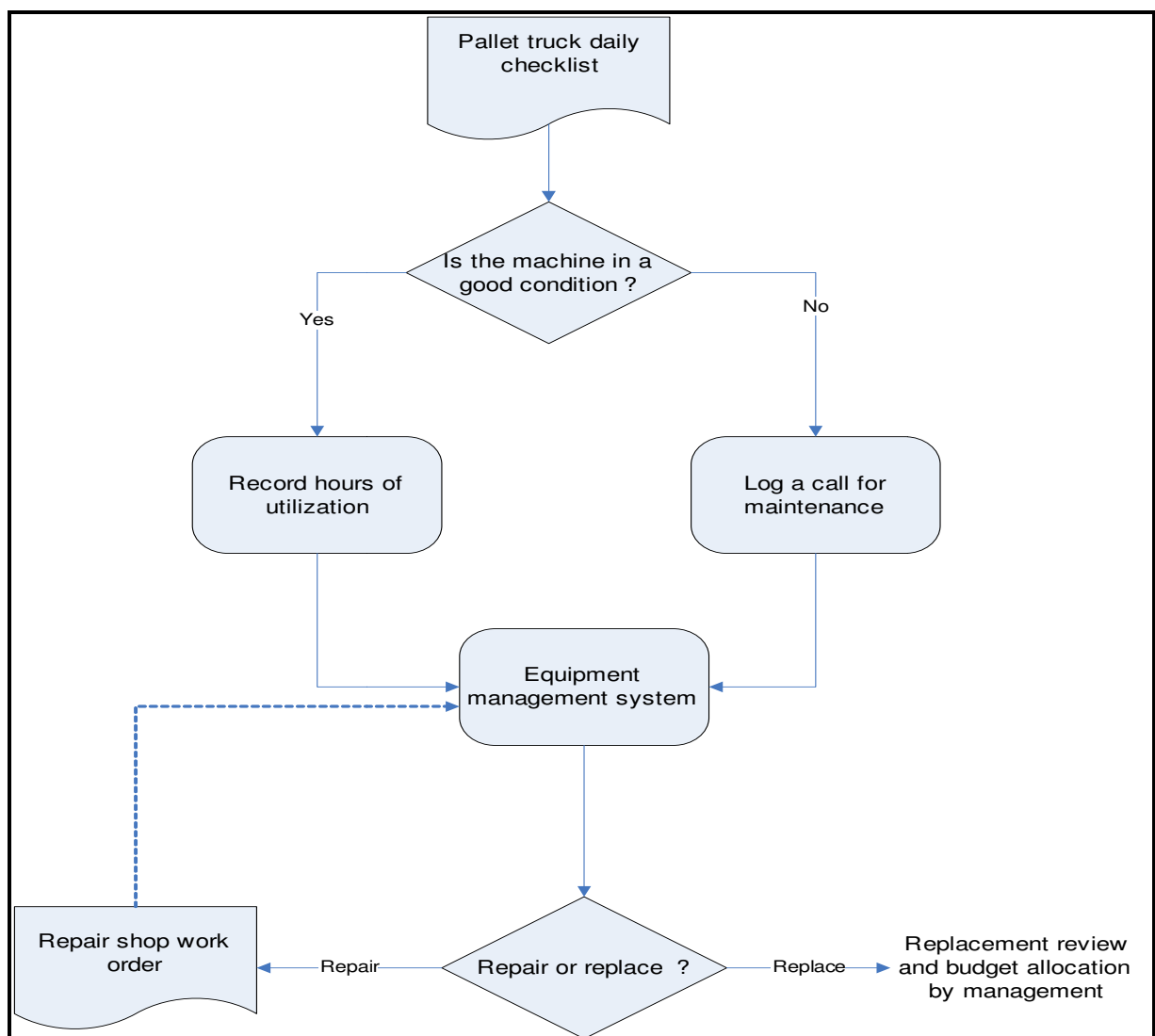


Figure 10 Equipment information flow

3.3. Evaluation and conclusion

The initial aim of the project was to conduct a material handling equipment utilization study for the Nissan SA parts distribution centre. Such a study took place through the investigation of MHE functions and management principles within the warehouse. Various Industrial engineering techniques could be applied for such a study, but due to certain operational requirements and the lack of any substantial equipment data the development of an information system was chosen. The Equipment Management System developed, will be a new method for Nissan to capture, store and retrieve information on material handling equipment.

The system will allow the viewing of real time information concerning MHE. This information will be summarized in reports, queries and tables for the purpose of supporting the managers and the maintenance department in decision making. The following aspects of MHE management are especially supported by the EMS:

- Economic evaluation of different equipment alternatives
- Monitoring of equipment performance (utilization, availability)
- Equipment acquisition decisions
- Monitoring and controlling equipment operationally and financially

The consistent and correct use of the EMS could save the company a considerable amount of money. In order for the system to function fully it will require the support of the owners (warehouse management) and the governance of an equipment management policy. Through the analysis of the EMS results and recommendations to be made here, management can set such policies. Although the EMS gives an indication of life cycle costing and assist in replacement decisions, the early or late replacement of equipment will ultimately depend on the governing policies of the company.

3.2.1 Critical findings and recommendations

Nissan PDC owns a fleet of 19 lift trucks, which is a collection of forklifts, reach trucks, order pickers and pallet trucks. It was noted that the most substantial breakdowns take place with the forklifts. Forklifts are essential for the smooth flow of products as they are mostly used at receiving/ inbound. Breakdowns of this equipment can be attributed to rugged external conditions (as they are used outside and at entrances of the warehouse), negligence and old

age. Nissan owns 6 forklifts, which in any given moment 3 can be down for the day. Four of these forklifts are about 10 years old.

The average acquisition cost of a forklift owned by Nissan SA is as follows:

- ± R 220 000.00

The estimated average book value

- ± R 64 000.00

With the operating cost of:

- ± R 120 per hour

Which means that the company is paying over R130 000 in maintenance per forklift every year, therefore $6 \times \pm 130000 = \pm R780\ 000$. With the cost of downtime this can go over just a million.

The average cost of renting a forklift for Nissan:

- ± R 6200 per month

The average maintenance cost:

- ± R 4100 per month
- In total this amount to ± R 10300 per month. Which is the same as $6 \times R123600 = \pm R741600$ per year.

The following averages were estimated from different material handling websites but taking into account the average size and age of equipment used by Nissan. All the maintenance costs are subject to price escalation yearly.

It is recommended that Nissan SA consider taking a 3 to 5 years rental contract for their forklifts. This will reduce their operating cost considerably and maintenance turnaround times can be arranged with the rental company. This will ensure that forklifts are consistently operational instead of causing a bottleneck for the rest of the warehouse. The four old forklifts giving the most problems can be sold with the yield of over R600 000. It is estimated that the rental of forklifts will save the company ± R200000 annually due to a reduction in equipment breakdowns.

3.2.2. Conclusion

Microsoft Access 2003 was used to develop the EMS prototype (See attached CD). Access 2003 was chosen because it is easy to use and it is already used throughout the organisation and it will be used for the foreseeable future. The information system was tested for its functionality and for how well it met stakeholder requirements using theoretical data. The results obtained met the initial requirements and through this system an equipment utilization study may be further conducted.

The implementation of the EMS will be the decision and responsibility of Nissan SA management. Thus a user manual has been developed to aid in assisting the employees with using and navigating the Equipment Management System (Refer to appendix).

3.4. References

Bentley, L.D. and Whitten, J.L. (2007), *Systems Analysis & Design for the Global Enterprise*, 7th edition, McGraw-Hill

Borghagen, L. (2004) "life cycle cost analysis", *Maynard's Industrial Engineering Handbook*, [Online] accessed: 11/05/2009, Available on: www.digitalengineeringlibrary.com

Cato, W.W. and Mobley, K.R. (2002) *Computer Managed Maintenance Systems: A step by step guide to effective management, labor, and inventory*, 2nd edition, Butterworth-Heinemann

Celik, H. and Gunal, A. (2006) Generic Approach to Material Flow Simulation using AutoMod, [Online] accessed: 11/03/2009 Available on: www.pmc Corp.com

Chase, R.B., Jacobs, F.R. and Aquilano, N.J. (2007), *Operations Management for Competitive Advantage*, 11th edition, McGraw-Hill

Coyle, J.J., Bardi, E.J. and Langley, C.J. (2003), *The Management of Business Logistics: A Supply Chain Perspective*, 7th edition, Thomson learning

Duffuaa, S.O., Raouf, A. and Campbell, J.D. (1999), *Planning and Control of Maintenance Systems: Modelling and Analysis*, John Wiley & Sons

Eastman, R.M. (1987), *Materials Handling*, New York: Marcel Dekker, Inc.

Hassan, M.M.D. (2002), "A framework for the design of warehouse layout", *Facilities*, 20(13/14), pp 432-440, [Online] accessed: 06/05/2009 Available on: www.emeraldinsight.com

Jooste, J.L. and Page, D.C. (2004) "A performance management model for physical asset management", *South African Journal of Industrial Engineering*, 15(2), pp 45-66

Kelton, W.D., Sadowski, R.P. and Sturrock, D.T. (2007), *Simulation with Arena*, 4th edition, McGraw-Hill

Lane, D.A. (2004), "Material Handling", *Maynard's Industrial Engineering Handbook*, [Online] accessed: 11/05/2009, Available on: www.digitalengineeringlibrary.com

Masilela, M.L. (2006), Management System for Forklifts and Tow Motors. University of Pretoria Nissan corporate information [Online] accessed: 17/03/2009, Available on: www.nissan.co.za

Piperakis, M. and Pouris, A. (2006) "The state of research equipment in South Africa: Towards best practice", *South African Journal of Industrial Engineering*, 17(1), pp75-90

Tompkins, J.A., White, J.A., Bozer, Y.A. and Tanchoco, J.M.A. (2003), *Facilities Planning*, 3rd edition, John Wiley & Sons

U.S. Department of Transport (1978), Equipment Management System

Yurtsever, T. and Comerford, M. (1995), Equipment Management System (EMS)

[Online] accessed: 13/03/ 2009, Available on <http://ieeexplore.ieee.org>

Price estimates:

www.buyerzone.com/library

www.nissanforklifts.com

www.crown.com

3.5. Appendix

Appendix A: Pallet truck daily checklist

Appendix B: Repair shop work order

Appendix C: EMS User manual

A. Pallet truck daily checklist

PIPES AND HOSES	FORKS	BATTERY WATER	BATTERY TERMINALS	PARK BRAKE	STEERING CONTROL	WHEELS	EXTERNAL LEAKS																												
PALLET TRUCK DAILY CHECKLIST																																			
HYDRAULIC OIL	Truck No..... Operator Name..... Supervisor Name..... Department..... Date week starts..... Date week ends..... Truck Meter Reading.....						FOOT BRAKE																												
STEERING CONTROL	MACHINE CONDITION <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> BEFORE SHIFT <input type="checkbox"/> M <input type="checkbox"/> T <input type="checkbox"/> W <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> S </div> <div style="text-align: center;"> AFTER SHIFT <input type="checkbox"/> M <input type="checkbox"/> T <input type="checkbox"/> W <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> S </div> </div>						HOOTER																												
HYDRAULIC CONTROL	REMEMBER SAFETY FIRST! 1. Carry operator's Identification Card 2. Overall 3. Safety shoes 4. Hard hat						GAUGES																												
DRIVE AND WORK SAFELY				REPORT UNSAFE ACTS																															
REPORT DEFECTS				REPORT INCIDENTS																															
NO SMOKING!!!																																			
<table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th style="width:25%;">Date</th> <th style="width:25%;">Hours worked</th> <th style="width:25%;">Service hours</th> <th style="width:25%;">Repairs hours</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> </tbody> </table>								Date	Hours worked	Service hours	Repairs hours																								
Date	Hours worked	Service hours	Repairs hours																																
Service hours- charging, refueling				Repair hours- PM or CM																															
Daily condition to be indicated by operator in blocks against applicable items																																			
<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> = Satisfactory M T W T F S				<input checked="" type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> = Requires attention and should M T W T F S be reported to supervisor immediately. Job card to maintenance department.																															

(Modified Nissan checklist)

